A Comparative Study on Various Blood Pattern on Different Surfaces

Sneha Sinha[1] & Aditya Kumar[2*]

[1,2]*Programme of Forensic Science, Faculty of Science, Assam down town University, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati, Assam-781026, India. Corresponding Author Email: aditya.kumar@adtu.in[*]*

ABSTRACT

One essential forensic technique for reconstructing the events of violent crimes involving bloodshed is bloodstain pattern analysis (BPA). The shape and diameter of blood droplets from four common species—humans (*Homo sapiens sapiens*), pigs (*Sus scrofa domestica*), goats (*Capra ibex*), and chickens (*Gallus gallus*)—are analysed in this study to investigate inter-species differences in bloodstain patterns. Blood samples were dropped onto twelve distinct horizontal surfaces, including cardboard, glass, metal, cotton fabric, and tile, from a fixed height of 14 inches. The findings advance our knowledge of BPA in forensic investigations by demonstrating how stain morphology is influenced by surface texture and species-specific blood characteristics. In addition to offering useful reference data for differentiating between human and animal blood in forensic casework, these discoveries improve the accuracy of crime scene reconstructions.

Keywords: Bloodstain Pattern Analysis; Forensic Science; Porous Surface; Non-Porous Surface; Spatter; Impact Stains; Transfer Stains; Passive Stains; Projected Stains; Pooling Blood; Luminol; Species Comparison.

1. Introduction

A crucial forensic technique for reconstructing the sequence of events leading to bloodshed during violent crimes is bloodstain pattern analysis (BPA) [1].

Analysts can deduce the kind of force used, the direction in which blood flows, and the chronology of events by looking at the size, shape, and distribution of bloodstains. The forces acting on a blood drop and the makeup of the blood itself determine the size [8], form, and general look of the resulting bloodstain, making its evolutionary development a complex process [1].

The complex system known as biological liquid is made up of many parts, such as cells and macromolecules, that are suspended in an aqueous phase. When a drop of biological liquid is allowed to dry on a solid substrate that is both wettable and non-porous, the "coffee ring" effect is visible. Through blood splatter, we can reconstruct the crime and start documentation [3].

Animal blood (porcine or bovine) provided by butcheries, human blood obtained from subjects, and blood replacement goods created in other nations are used in experiments and bloodstain pattern analysis courses [2]. Human blood has several issues, such as the subjects' resistance to blood collection, the potential for unpleasant odors and decomposition, the risk of biological infection, the challenge of providing a large volume of blood when necessary, and the challenges of controlling experimental conditions because of the alteration in physical characteristics brought on by the use of anticoagulants.

BPA is a valuable forensic technique in addition to autopsies, general crime scene investigation, and molecular biology [11]. In case of latent blood detection, the luminescence seen when a solution of luminol and hydrogen peroxide is sprayed onto dried bloodstains has been used by forensic scientists in the investigation of violent crime for over 40 years [6].

1.1. Study Objectives

The objective of the review is to critically evaluate existing literature on bloodstain pattern analysis (BPA), with a focus on how blood behaves on different surface. Specifically the paper aims to:

(1) To examine how blood from different species forms patterns on various surface types, (2) To compare the morphology of bloodstains on porous and non-porous surfaces, (3) Summarize the principles of BPA and its forensic application, (4) Identify gaps in current research and purpose direction for further studies, and (5) To understand how surface interaction alters stain interpretation in forensic contexts.

2. Types of blood pattern

2.1. Passive Bloodstains (Gravity-Influenced Patterns)

Produced by gravitational force acting on liquid blood.

Surfaces: • Smooth, Non-Porous (Glass, Metal, Tile). • Clearly defined, circular marks. • Limited spatter or distortion observed. • Rough, Porous (Concrete, Wood, Fabric): • Uneven edges resulting from absorption. • Larger stain dimensions on absorbent materials such as fabric.

2.2. Transfer Bloodstains (Contact Patterns)

These patterns arise when an object that has blood on it makes contact with another surface.

Surfaces: • Smooth, Non-Porous: • Sharp, detailed transfer impressions (e.g., fingerprints, shoe prints). • Porous (Paper, Fabric): • Obscured or smeared patterns due to absorption.

2.3. Impact Spatter Patterns (Force-Driven Bloodstains)

These patterns result from an external force impacting a blood source. The size of the droplets is contingent upon the applied force.

Surfaces: • Smooth, Non-Porous (Glass, Plastic): • Small, distinct droplets with minimal distortion. • Spatter disperses widely. • Rough, Porous (Wood, Concrete, Fabric): • Irregular, absorbed droplets. • Satellite spatter may blend with the texture of the surface.

2.4. Projected Bloodstains (Blood Under Pressure)

These stains occur when blood is forcefully expelled from a body, such as during arterial spurts or coughing.

Surfaces: • Smooth, Non-Porous, Exhibit clear, elongated patterns with a distinct direction of flow Porous (Fabric, Carpet): • Patterns may become distorted or absorbed, complicating interpretation.

2.5. Pooling Bloodstains (Blood Accumulation)

A significant volume of blood gathers in a specific area as a result of extended bleeding.

Surfaces: • Smooth, Non-Porous: • Characterized by well-defined edges, with blood remaining on the surface. •Porous (Carpet, Cloth): • Blood spreads outward through absorption, making it challenging to identify boundaries.

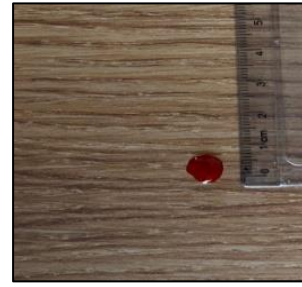**Figure 2.1.** Glass Surface

Figure 2.2. Cloth Surface
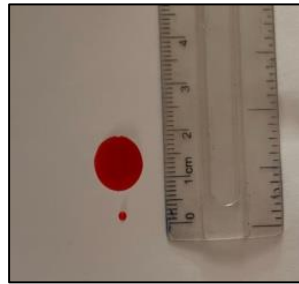

Figure 2.3. Wood Surface
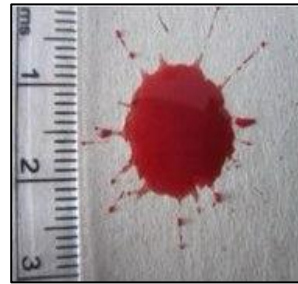

Figure 2.4. Paper Surface

Figure 2.5. Cardboard Surface

3. Experimental Study on Blood Patterns

Blood interacts differently to surfaces because of its special characteristics, such as surface tension viscosity, and non-Newtonian fluid behavior. Bloodstains have previously been divided into three categories according to impact velocity: low velocity (such as drops caused by gravity), medium velocity (such as blunt force injuries), and high velocity (such as gunshot wounds). Researchers such as Mac Donell, James, and Sutton made important contributions to the early research in this discipline, which began in the late 19th and early 20th centuries.

Similar to a guiding light in this discipline, blood spatter analysis clarifies unclear areas. As the investigator deciphers the enigmatic blood-stained drawings, they find a map that depicts the motions and acts that created the sight before them. The patterns of tiny drops identify the impact of a forceful blow, the trajectory of an object moving through the air, and the speed of a collision, all of which are waiting for someone perceptive enough to decipher their meaning [8],[9].

The fundamental decision of this study is the audacious use of goat blood, a modest but crucial alternative, to mimic the functions of human blood. The study of species similarities is the subject of this text.

4. Materials and Methods

4.1. Sample Collection

Human blood was drawn from the blood bank, and samples of pig, goat, and chicken blood were acquired from butcher shops in Assam, Guwahati. The samples were utilized right away for the tests and kept in 100 ml polypropylene vials with EDTA as an anticoagulant.

4.2. Methods

Using a bat or other comparable instrument, strike a blood supply (such as saturated sponge) that has been placed on a surface to stimulate high velocity splatter used as rifle stimulator or compressed air equipment (while taking the

safety precautions) on different surfaces. Bloodstain patterns were documented and measured for various in diameter, shape, size, direction.

Figure 4.1. Measurement of Blood Pattern

5. Result and Discussion

Depending on the impact's velocity and kind, impact spatter is a distinctive pattern that is produced when force is delivered to a blood source on different surface. The anticipated outcomes based on varying force levels are listed below:

5.1. Impact Spatter at Low Velocity (Blunt Force Trauma) for instance, punching or striking with a hammer, bat, or other blunt implements

1. Droplet Size: Large, with a diameter of at least 4 to 8 mm.

2. Distribution: Limited travel distance, clustered with uneven edges. The majority of blood stains are round or slightly elongated in appearance. Usually located within 1–4 feet of the source, there aren't many satellite stains surrounding the core impact area.

3. Use: Signals a close-quarters assault using a blunt weapon.

5.2. Non-porous, smooth surfaces (plastic, tile, metal, glass)

1. Circular or slightly elongated stains that are well delineated.

2. Blood stays on the surface with little absorption.

3. There aren't many satellite stains, which are tiny drops surrounding the primary stain.

5.3. Semi-porous (wood, laminated floors, painted walls)

1. Partial absorption causes the blood borders to appear somewhat fuzzy.

2. Some blood soaks into the material due to absorption; moderate satellite stains

6. Conclusion

The surface type has a significant impact on the appearance, dispersion, and interactions of blood splatter with its surroundings. Because smooth surfaces maintain droplet shape, they are perfect for forensic force and angle

investigation. Rough and porous surfaces might break up or absorb blood, making analysis more difficult and necessitating augmentation procedures. Blood patterns are distorted by wet or slick surfaces, which makes estimating the time of crime challenging. Blood behavior can reveal impact force, direction, and velocity, therefore forensic investigators must take surface interactions into account when recreating crime scenes.

7. Recommendations

The set of surfaces used in future experiments should be expanded to include more types of surfaces, including irregular or sloped surfaces, to better represent real crime scenes. Further comparisons with other animal species (such as bovine or rodent) can contribute to an enhanced substitution validity from human blood. Further investigations are needed on the influence of time between blood collection and pattern formation, especially in anticoagulant-treated sample.

References

[1] Bevel, T., & Gardner, R.M. (2008). Bloodstain pattern analysis: With an introduction to crime scene reconstruction (3rd Eds.). CRC Press Chapter 9, titled "Evaluating Impact Spatter Bloodstains," which begins on Page 199, Chapter 5, titled "The Medium of Blood," Starting on page 111. https://doi.org/10.1201/9781420052/25.

[2] Attinger, D., Moore, C., Donaldson, A., Jafari, A., & Stone, H.A. (2013). Fluid dynamics topics in bloodstain pattern analysis: Comparative review and research opportunities. Forensic Sci. Int., 231(1–3): 375–396. https://doi.org/10.1016/j.forsciint.2013.05.014.

[3] Deegan, R.D. (2000). Pattern formation in drying drops. Phys. Rev. E., 61(1): 475–485. https://doi.org/10.1103/physreve.61.475.

[4] Hulse-Smith, L., Mehdizadeh, N.Z., & Chandra, S. (2005). Deducing drop size and impact velocity from circular bloodstains. J. Forensic Sci., 50(1): 54–63. https://doi.org/10.1520/jfs2004211.

[5] James, S.H., Kish, P.E., & Sutton, T.P. (2005). Principles of bloodstain pattern analysis: Theory and practice. CRC Press. https://doi.org/10.1201/9781420039467.

[6] Weber, M., & Kooman, G. (1981). Luminol chemiluminescence: A forensic method for the detection of blood. J. Forensic Sci., 26(3): 564–570. https://doi.org/10.1520/jfs10853j.

[7] MacDonell, H.L. (1971). Flight characteristics and stain patterns of human blood. U.S. Army Office of the Provost Marshal General.

[8] Laan, N., De Bruin, K.G., Bartolo, D., Josserand, C., & Bonn, D. (2015). Maximum diameter of impacting liquid droplets. Phys. Rev. Appl., 4(4): 044018. https://doi.org/10.1103/physrevapplied.4.044018.

[9] Adam, C.D. (2012). Fundamental studies of bloodstain formation and characteristics. Forensic Sci. Int., 219(1–3): 76–87. https://doi.org/10.1016/j.forsciint.2011.11.019.

[10] Dennington, T., McDonagh, A.M., & Roux, C. (2008). Evaluation of blood simulants used in bloodstain pattern analysis. Forensic Sci. Int., 180(1): 23–31. https://doi.org/10.1016/j.forsciint.2008.06.015.

[11] Tulleners, F.A., & Chisum, W.J. (1992). Crime scene reconstruction. Forensic Sci. Rev., 4(1): 1–19. http://www.elsevierdirect.com/companions/9780123864604.